APPENDIX C

CLASS I, FILTRATION WITH PRESSURIZATION

C-1. Existing Facility Classification.

Existing facilities can be separated into four classes that reflect their potential to support the integration of a CP system.

a. *Class IA*. This class of facility is capable of fully integrating the CP overpressure system with the facility heating, ventilating, and air-conditioning (HVAC) system. The HVAC system may not be specifically designed for a CP overpressure system, but it is capable of fully maintaining the facility temperature during CP system operation. The CCA will be outside of the facility or under an open-air overhang, roofed shelter, or tent.

b. *Class IB*. The facility HVAC system is capable of partial integration of the CP overpressure system. The HVAC system may require upgrades to existing ductwork and isolation of the ductwork used for normal HVAC facility operations. The HVAC system may not be capable of maintaining original design conditions without modification and may require supplemental heating and cooling. The CCA will be outside of the facility or under an open-air overhang, roofed shelter, or tent.

c. *Class IC*. The facility HVAC system is not capable of integrating the CP overpressure system. The facility design temperatures cannot be maintained without supplemental heating and cooling from the CP overpressure system. The CCA will be outside of the facility or under an open-air overhang, roofed shelter, or tent.

d. *Class ID*. The facility cannot be sealed economically to maintain an overpressure, but it is suitable for portable enclosures or liner systems set up internally with advance warning. This type of arrangement allows the existing HVAC system to partially or fully maintain the facility design temperature outside the inflatable liner or shelter. Examples are warehouses, hangers, and maintenance bays.

C-2. Guidance.

New Class I CP facilities will be designed as Class 1A; i.e., capable of maintaining the facility temperature during collective protection operations. New collective protection facilities with an integral CCA will be designed in accordance with TM 5-855-1 and other criteria as designated by the using command having jurisdiction.

C-3. Design Requirements.

Major considerations for the design of CP systems for both existing and new facilities are listed below. Requirements for each item are discussed in subsequent paragraphs.

a. *Button-Up Period and Floor Area Requirements*.

b. *Toxic-Free Area Envelope*.

c. *Airlock Requirements*.

d. *Toxic-Free Area Overpressure*.

e. *Toxic-Free Area Envelope Air Leakage Rate and Sealing Measures*.

f. *Collective Protection Overpressure System Design*.

g. *Collective Protection Control System and Operational Requirements*.

h. *Operation and Maintenance*.

C-4. Button-Up Period and Floor Area Requirements.

The CP button-up period is determined by the command or authority having jurisdiction and can range from several hours to several days. For off-site industrial accidents, the button-up period is usually less than 24 hours. Button-up periods longer than 24 hours are generally restricted to wartime. The button-up period influences the floor area requirements and the amount of consumable and waste storage. Generally, the button-up period will not significantly affect the performance of the CP system.

a. *Less Than 24 Hours*. A button-up period less than 24 hours does not require sleeping areas. The occupant load will generally be a net 1.86 m^2/person (20 ft^2/person) depending upon the classification of occupancy. The classification of occupancy, as stated in NFPA 101, may require a higher or lower occupant loading depending upon the building classification. The occupant loading will be coordinated with the authority having jurisdiction.

b. *More Than 24 Hours*. A button-up period greater than 24 hours requires sleeping areas. The minimum floor area, with the use of single size beds, is approximately 5.6 m^2/person (60 ft^2/person). With the use of bunked beds, the minimum floor area is approximately 2.8 m^2/person (30 ft^2/person).

C-5. Toxic-Free Area Envelope.

The total required TFA floor space is determined from the button-up period, the number of people sheltered, and the required floor area per person. Generally, large open areas such as common areas, multipurpose areas, gymnasiums, etc., provide the most efficient floor area for protecting a large number of personnel. The TFA envelope should include bathroom facilities and, if possible, kitchen facilities.

C-6. Airlock Requirements.

Personnel that ingress and egress the TFA during CP operations must process through an airlock. The airlock maintains TFA overpressure, prevents the migration of airborne contaminants into the TFA, and purges contaminants from personnel before they enter the TFA. The number of airlocks required depends on the number of personnel that ingress and egress during a given time period.

a. *Stand-Alone Airlock*. For existing facilities, the stand-alone two-stage airlock discussed in Appendix F will be used. This airlock is designed to process two people into the facility within 8 minutes with 4 minutes in the first stage and an additional 4 minutes in the second stage. An integral 94 L/s (200 cfm) air filtration unit is used to provide the necessary air purge rate upon which the dwell time is based.

b. *Integral Airlock*. For new facilities, the integral single-stage airlock discussed in Appendix F will be incorporated into the vestibule area. The airflow purge rate through the single-stage airlock will provide a 3 log reduction in contaminants based on equation C-1.

$$Q = \frac{6.9V}{T} \qquad \text{(eq C-1)}$$

where:
Q = airflow, cubic meters per minute
V = airlock volume, cubic meters
T = purge time, minutes

Airlock airflow is driven by internal overpressure from the TFA. Uncontaminated air from the TFA will enter the airlock near the ceiling and exhaust near the floor. The airflow rate through the TFA will be monitored by an airflow measuring station or measuring device that can be field calibrated, and the airflow rate will be displayed at a CP control panel. The airflow rate through the airlock will be controlled by a flow control damper and backdraft damper. A warning light will illuminate when the airflow rate drops below design values. The static air pressure drop from the TFA to the airlock and from the airlock to the exterior will not exceed 25 Pa (0.1 inch wg) at each location, giving a total airlock static pressure drop of not more than 50 Pa (0.2 inch wg).

C-7. Toxic-Free Area Overpressure.

The minimum TFA overpressure will be 75 Pa (0.3 inch wg). This corresponds to a wind speed impact pressure normal to a wall of 40 km/hr (25 mph). After installation of the overpressure system, it is possible that a TFA pressure higher than the 75 Pa (0.3 inch wg) will result. A higher pressure provides a higher factor of safety for the CP system and should not be intentionally lowered to maintain a 75 Pa (0.3 inch wg) overpressure.

C-8. Toxic-Free Area Envelope Air Leakage Rate and Sealing Measures.

a. *Existing Facilities*. To determine the envelope air leakage rate for existing facilities, an air leakage measurement test using a blower door assembly will be performed in accordance with ASTM E779. Test data will be plotted on a log-log graph for ease of data extrapolation and review. Air leakage locations can be identified during pressurization testing when the blower door assembly is operated in the negative pressure mode and draws outside air into the proposed TFA. These leakage locations can also be identified by physical inspection or with smoke testing. Leakage areas will be sealed with a good quality sealant or, if necessary, reconstructed. Weather sealing measures can be expected to achieve leakage reductions in the range from 5 to 50 percent depending on the type and quality of facility construction. Sealing of the TFA envelope will reduce the air leakage rate and thus reduce the required amount of filtered air. Sealing measures must be economical when compared to the cost of the filtration and HVAC equipment and, for continuously operated CP facilities, energy usage must also be considered. After sealing, a second blower test will be conducted to determine the final TFA envelope air leakage rate.

b. *New Facilities*. For new facilities, the TFA envelope air leakage rate will be calculated using the effective leakage area procedures in the ASHRAE Handbook of Fundamentals. The leakage calculations will be performed for the TFA envelope including the walls, roofs, floors, doors, windows, sole plates, mechanical and electrical penetrations, ceiling-wall joints, isolation dampers, etc. The overpressure of the TFA will be used as the differential pressure in determining the TFA envelope leakage rate. Appendix G will be used as a guide to confirm the TFA envelope unit leakage rate as determined by the calculations. Care should be taken during design and construction to ensure that proper sealing of penetrations is performed and that continuous air leakage control barriers are used in the TFA envelope. A blower door test of the TFA envelope should be performed to verify the leakage rate and ensure that the CP overpressure filtration system has sufficient capacity.

C-9. Collective Protection Overpressure System Design.

a. *Airflow Filtration Capacity*. The airflow capacity of the CP overpressure filtration system is the sum of the following three components: TFA envelope air leakage rate at the design pressure differential, the ventilation air intake rate that meets exhaust requirements, and the airlock airflow necessary to achieve the required purge rate. The CP filtration system blower total static pressure will be designed to include the filtration system with dirty filters, ductwork system pressure losses, and the overpressure requirement of the TFA. The HVAC system must be designed, operated, and maintained to provide uncontaminated air to the TFA. It will be located in a contamination-free mechanical room to insure that negative pressures induced in the ductwork by HVAC equipment located in the mechanical room will not draw in contaminated air to the protected area. Filtration systems will conform to Appendix E.

b. *HVAC Requirements*.

(1) Existing Facilities. For existing facilities, an engineering evaluation will be performed to determine if the existing HVAC equipment can be used for CP operations to maintain the designed indoor air temperatures for both the summer and winter design conditions. The final indoor temperature for the summer and winter design conditions will be coordinated with the user and, if necessary, mechanical equipment modifications or additional heating and cooling equipment will be added to meet user requirements. For Class IC facilities that do not require the system to maintain above freezing indoor conditions during low outdoor ambient conditions, water utilities must be protected from freezing during CP operations.

(2) New Facilities. For new facilities, the HVAC equipment will be designed to incorporate the requirements of the CP overpressure system and maintain indoor design conditions. The outside air intakes will be located in an inaccessible location or secured by use of a standoff distance that inhibits the direct insertion of contaminants.

(3) Outside Air Occupant Ventilation Rate. The target outside air intake rate per occupant will conform to ASHRAE Standard 62. If during CP operations the fresh air intake rates required in ASHRAE Standard 62 cannot be maintained, lower air intake rates can be used. The lower fresh air intake rates cannot be used for normal operations but only during CP operations. Different levels of indoor air quality (IAQ) can be used depending upon user requirements and facility restrictions. To maintain IAQ based upon the ASHRAE Standard 62 acceptable indoor carbon dioxide level of 0.1 percent, a minimum air intake rate of 7 L/s (15 ft^3/min) can be used. The lower recommended limit of fresh air intake is based on a carbon dioxide limit of 0.5 percent or a minimum outside intake rate of 1.4 L/s (3 ft^3/min). However, 2.4 L/s (5 ft^3/min) should be used as the practical lower limit. For facilities that cannot meet the carbon dioxide level of 0.1 percent, a carbon dioxide detector will be provided that will alarm at a level 50 percent higher than the expected carbon dioxide value, but not more than 0.8 percent. Normally, the filtered outside air intake required to pressurize the TFA will exceed the occupant ventilation rate.

c. *TFA Envelope Isolation and Control*.

(1) Ductwork. Ductwork that serves the TFA during normal operation but is not required during CP operations will be closed off and isolated by use of low-leakage dampers at the TFA envelope. During CP operations, the TFA overpressure system will maintain pressure on the isolation dampers under all conditions and thereby eliminate entrance of contaminated air into the TFA. Isolation damper position indicators will be included to provide visual identification of the open and closed positions. Additionally, the isolation damper position will be visually annunciated

at the system control panel. The leakage rating of the isolation dampers will be selected based on an economical comparison of damper leakage and additional filtration capacity.

(2) Doors. Doors at the TFA envelope will be weather sealed to reduce the air leakage rate. The door position will be monitored and visually annunciated at the system control panel.

C-10. Collective Protection Control System and Operational Requirements.

The CP control system will be located in the TFA, preferably in a utility room. The CP system will be energized by one control panel switch that de-energizes other facility systems not required during CP system operations. Examples of these systems are normal outside air fans, exhaust fans, and recirculation fans that are in the building but outside the protected envelope. The control system will monitor the position of all isolation dampers and doors by use of an annunciator light at the control panel. All device positions; i.e., either open or closed, will be annunciated at the CP control panel. A green indicator light will annunciate if the damper or door is in the correct position during CP system operation. A red indicator light will annunciate if the damper or door is not in the correct position or if a problem has occurred. The TFA overpressure with reference to the atmosphere will be monitored and displayed on the CP control panel. To maintain the TFA overpressure, the airlock doors must not be opened simultaneously.

C-11. Operation and Maintenance.

a. *CP System Operational Testing*. Standby CP systems should be tested once each month to ensure that they are in good operating condition. For continuously operated systems, periodic system monitoring should be performed to ensure the CP system is operating properly.

b. *Filter System*. In addition to the manufacturer's recommended maintenance requirements, the following filter replacement and testing requirements should be performed.

(1) High-Efficiency Particulate Air (HEPA) Filter. The initial resistance of the HEPA filter is typically 250 Pa (1.0 inch wg). The HEPA filter should be replaced when it is loaded and the static pressure differential reaches about 750 Pa (3.0 inches wg). The HEPA filter pressure drop will be monitored at the CP system control panel with annunciation when the dirty filter pressure drop is reached. The HEPA filter will be mechanically leak tested after filter replacement.

(2) Adsorption Filter. The adsorber filter should be replaced as required in FM 3-4 and mechanical leak tested with a test gas after filter replacement.

(3) Airflow Testing. The filtration system airflow rate should be periodically tested and re-balanced as necessary to maintain the design airflow rate. The filtration system should also be airflow tested after prolonged use. A HEPA filter without a prefilter could be fully loaded after 9 months of continuous use. Utilizing a prefilter will extend the life of the HEPA filter to about 2 years of continuous use.

(4) Filtration System Testing. The filtration system will be field leak tested by an independent testing agency after installation. The system should also be mechanical leak tested every 12 months and after replacement of the HEPA filter or adsorber filter. The design must ensure that adequate filter access is provided.

c. *Signage*. Doors required to be closed during overpressure will be labeled as such on red background signage. Doors required to remain open during overpressure will be labeled as such on green background signage.

d. *Training*. Training should be conducted for all facility personnel that may be called upon to operate the CP system.

e. *Operating Instructions*. Operating instructions and system diagrams for the CP system will be displayed next to the CP system control panel at eye level. Operating instructions will describe, in short and concise language, the steps required to operate the CP system. All CP system control switches and indicators will be clearly marked and identified.

f. *Operation and Maintenance Manual*. An operation and maintenance manual will be provided and will contain system operating instructions, emergency operation instructions, preventive maintenance information, troubleshooting, corrective maintenance, periodic maintenance recommendations, critical instructions, and a spare parts list.